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Consistency and Quality of USNO Analysis Center Products

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Abstract – **The United States Naval Observatory (USNO) has participated in the International GNSS Service (IGS) as an analysis center (AC) since 1997. This report summarizes the quality and consistency of USNO rapid and ultra-rapid submissions. The consistency of our submissions has steadily improved over the years to where in 2007, we submitted 98% of the expected rapid- and ultra-rapid products. The quality has improved as well, with current values as follows. After subtraction of a seven-parameter coordinate transformation, the median value of the weighted root-mean-square residuals of the USNO orbits with respect to (wrt) the IGS combined rapid orbits are 24 mm (USNO rapid) and 58 mm (USNO ultra-rapid). Polar motion: root-mean-square (RMS) residuals wrt the IGS final products are ~65 µarc sec (rapid), 190 µarc sec (ultra, past 24-h) and ~360 µarc sec (ultra, 24-h predict). Polar motion rates (wrt IGS final products): ~180 µarc sec/d (rapid), ~200 µarc sec/d (ultra, past 24-h) and ~390 µarc sec/d (ultra, 24-h predict). Planned improvements to accuracy include implementation of absolute antenna phase-center corrections and addition of more stations to processing.**

I. Introduction

The United States Naval Observatory (USNO) has participated in the International GNSS (IGS) as an analysis center (AC) since 1997, submitting daily rapid products since that time, twice-daily ultra-rapid products since 2000, and four-times-daily ultra-rapid products since February, 2007.

In this article, we summarize how the consistency and quality of our products have improved over the years, and provide quality estimates for current products.

II. Consistency of USNO Products

Table 1 summarizes the percentage of expected products submitted and the number of stations processed.

Rapid products: Except for 1999 (94%) and 2001 (95%), the USNO has submitted 98-99% of the expected products every year. While during the years 1999-2004 an average of 33-34 stations were processed per rapid run, this number was increased to 43 in 2005 and 47 in 2006-2007. Once the transition to absolute phase centers is complete (see "Planned Improvements"), we hope to increase the number of stations further.

Ultra-rapid products: From 2001-2005 the USNO submitted 85-89% of the expected ultra-rapid products. Twice-per-day runs place a higher strain on personnel/network resources; the lower level of consistency in years past was thus no surprise. However, in 2006, the consistency improved to 94% and in 2007 (through December 1), it improved to 98%. The 2007 statistics are remarkable given the switch to four-times-per-day submissions in February, 2007. This improvement is due to more careful management of disk space and better handling of run-time problems. Staff diligence, including a proactive stance toward possible network outages, has also played a role.

Ultra-rapid products are computed using data from, on average, 34 stations. The average number of stations used has been as high as 40; we plan to increase the number of stations processed in these products as well.

The USNO products are created and transmitted by means of automated processes. The rapid products are computed using GIPSY-OASIS software developed by the Jet Propulsion Laboratory (Webb and Zumberge 1997); the ultra-rapid products are computed using software developed by the University of Bern (Dach *et al.* 2007). USNO personnel monitor the production of the rapid products, restarting stopped processes as needed. The ultra-rapid products are not actively monitored; however, staff are alerted via automatic email when the processes exit with an error.

III. Quality of USNO Products

Figs. 1-3 summarize the quality of USNO orbits, polar-motion and polar-motion-rate estimates. Orbits are compared to the IGS Combined Rapid Orbit; earth-orientation estimates to the IGS Final products.

IGS combined orbits are created by combining the independent orbit estimates submitted by the ACs. The quality of each submission can then be assessed by computing a seven-parameter coordinate transformation (translation, rotation and scale) between it and the combined orbit. The weighted root mean square (WRMS) of this transformation is a useful quality estimator, because it indicates to what extent the difference between the individual orbit and the combined orbit cannot be explained by a simple bias in coordinate systems. As Fig. 1 shows, the WRMS of USNO rapid orbits has improved from a median of approximately 60 mm (1999-2001) to 21-25 mm (2004-2007). The WRMS of the ultra-rapid orbits has undergone similar improvement, from 120-150 mm (2002-2004) to 58-60 mm (2006-2007). Note: while USNO rapid orbits are post-processed and based on the most recent 24-h of tracking data, USNO ultra-rapid orbits consist of two 24-h segments: a post-processed orbit based on the most recent 24-h of tracking data, and a 24-h predicted orbit. The WRMS comparison of the ultra-rapid orbits to the IGS rapid product is performed by lumping both segments together; information included in the IGS comparison summaries indicates that the combined WRMS is most likely dominated by the noise of the predicted part[1].

[1]See IGS ultra-rapid comparison summaries, on-line at (e.g., for the ultra-rapid orbit of GPS week 1458, day 0, 18.00 UTC) http://igscb.jpl.nasa.gov/igscb/product/1458/igu14580_18_cmp.sum Compare WRMS values for usu in Tables 1 (total WRMS) and 3 (WRMS of 24-h post-processed portion).

Fig. 2 shows the quality of USNO polar-motion estimates. The root mean square (RMS) agreement of the rapid products with the IGS final values has improved from ~100-180 μarc sec (1999-2003) to 50-70 μarc sec (2005-2007). Like its ultra-rapid orbits, USNO ultra-rapid earth-orientation parameter estimates consist of two sets of values: one post-processed set for the past 24 hours, and one predicted set for the next 24 hours. The RMS agreement of the post-processed ultra-rapid polar motion estimates has been in the 180-250 μarc sec range during 2005-2007; the RMS agreement of the predicted polar-motion values has been ~330-450 μarc sec.

Fig. 3 shows the quality of the corresponding polar-motion-rate estimates. The RMS of the rapid polar-motion-rate estimates (wrt IGS final values) has improved from ~500-520 μarc sec/d in 1999 to 150-200 μarc sec/d (2005-2007). The post-processed ultra-rapid polar-motion-rate estimates have had RMS' of ~190-230 μarc sec/d over 2005-2007; the ultra-rapid predictions of polar-motion rates have improved steadily over 2005-2007 to the 2007 values of 437 (x-pole-rate) and 365 (y-pole-rate) μarc sec/d. The ultra-rapid prediction of x-pole rate appears to be worse than that of the y-pole rate; at present, we have no explanation.

IV. Planned Improvements

The USNO AC can improve its products first and foremost by implementing measurements of absolute antenna phase-center offsets as mandated by the IGS (IGS Mail 5438, 2006). This long-overdue transition should occur in early 2008. Plans are also underway to increase the number of stations included in the computations. This latter development goes hand-in-hand with current internal efforts to modernize hardware and to streamline software processes.

V. Conclusions

The quality and consistency of USNO products have shown gradual, steady improvement. We look forward to continuing our collaboration with the IGS.

Acknowledgments

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TABLE 1

CONSISTENCY OF AND NUMBER OF STATIONS USED IN USNO IGS SUBMISSIONS

	% submitted		# stations used	
	rapids	ultras	rapids	ultras
1999	94		33	
2000	98		34	
2001	95	87	34	25
2002	98	86	34	30
2003	98	89	34	40
2004	98	85	34	40
2005	99	88	43	37
2006	99	94	47	34
2007[a]	98	98	47	34

[a]through 1 December 2007

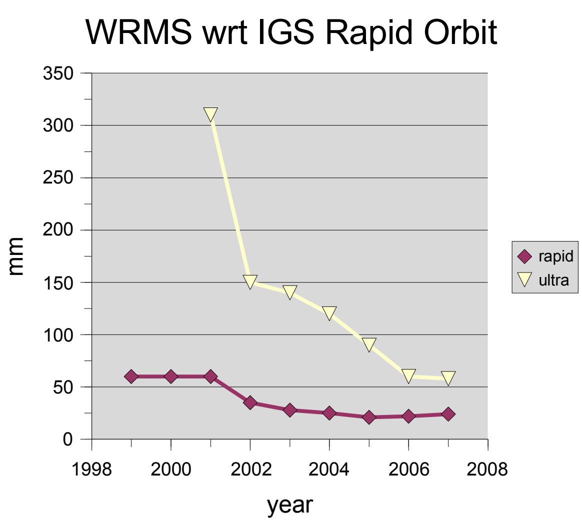

Fig. 1 Median WRMS of USNO satellite orbits with respect to (wrt) the IGS combined rapid orbit. The WRMS computed for the ultra-rapid product includes the fit of both the post-processed and predicted orbits wrt the IGS rapid. WRMS values for the ultra-rapid orbits were computed using the 00 and 12 UTC products. Includes data up through 1 Dec 2007.

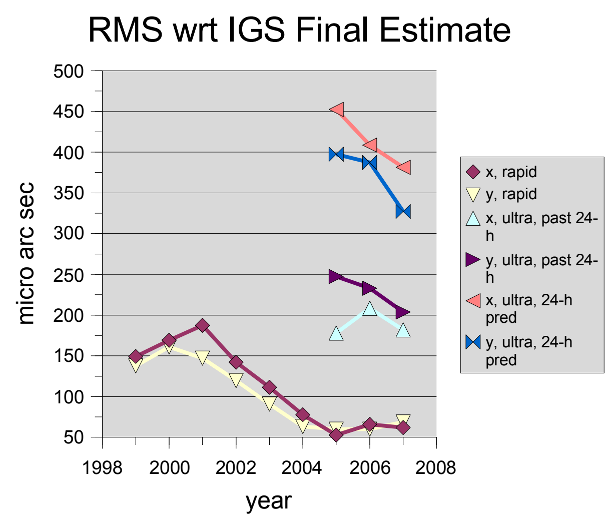

Fig. 2 RMS difference between USNO polar-motion estimates and those of the IGS final products. Ultra-rapid statistics are computed using only the 00 UTC products and begin on 11 Sep 2005. Includes values up through 8 Dec 2007.

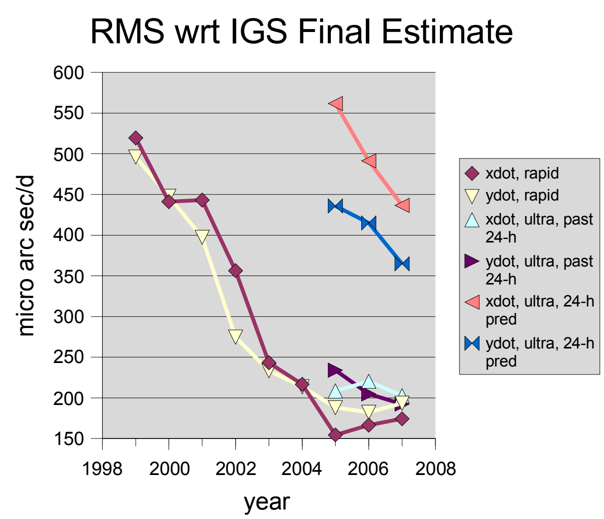

Fig. 3 RMS differences between USNO polar-motion rate estimates and those of the IGS final products. "xdot" and "ydot" = change of x-pole and y-pole position wrt time. Ultra-rapid statistics are computed using only the 00 UTC products and begin on 11 Sep 2005. Includes values up through 8 Dec 2007.